Educational Product	
Educators	Grades 5–8 & 9–12

The Potential Consequences of Climate Variability and Change

OVERVIEW ACTIVITIES FOR 5–12 EDUCATORS

Global Balance

AN ACTIVITY RESOURCE FOR TEACHERS

Responding to National Education Standards in:

- ***English Language Arts***
- ***Geography***
- ***Mathematics***
- ***Science***
- ***Social Studies***

This learning activity was developed to examine the potential impacts of climate variability and change. Each activity is part of an overall series entitled ***The Potential Consequences of Climate Variability and Change,*** which includes 1–12 teacher resources. Twelve modules (10 printed and 2 online resources) comprise the set and are presented below:

OVERVIEW

- Too Many Blankets (Grades 1–4)
- Global Balance (Grades 5–12)

AGRICULTURE

- El Niño (Grades 5–8)
  This activity is provided in an online format only and is available at *http://ois.unomaha.edu/casde/casde/lessons/Nino/teacherp.htm.*
- The Great American Desert? (Grades 9–12)
  This activity is provided in an online format only and is available at *http://ois.unomaha.edu/casde/casde/lessons/grass/teacherp.htm.*

COASTAL AREAS

- What Could a Hurricane Do to My Home? (Grades 5–8)
- What Is El Niño? (Grades 5–8,9–12)
- Coral Reefs in Hot Water (Grades 9–12)

FORESTS

- A Sticky Situation (Grades 5–8)
- Planet Watch 2000 (Grades 9–12)

HUMAN HEALTH

- Beyond the Bite: Mosquitoes and Malaria (Grades 5–8,9–12)
- Climate and Disease:A Critical Connection (Grades 9–12)

WATER

- Here, There, Everywhere (Grades 7–8,9–12)

The development of the activities was sponsored by the National Aeronautics and Space Administration and the Environmental Protection Agency, in support of the US Global Change Research Program. The Institute for Global Environmental Strategies implemented the effort. For more information,see *http://www.strategies.org.* For additional resources, please visit *http://teach earth.com*—Resources for Teaching and Learning about Earth System Science..

Climate Variability & Change

OVERVIEW ACTIVITIES FOR 5–12 EDUCATORS

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SIX ACTIVITIES
Global Balance

CONTENTS

Global Balance

This series of activities and experiments demonstrates the importance of "feedbacks" and the balance of mass and energy in governing the response of any system to change. Energy balance and the factors that cause change (feedbacks) are the keys to understanding climate change, and therefore the keys to understanding the effects of rising levels of greenhouse gases on the environment.

Although these activities are designed to teach specific skills and knowledge through scientific inquiry, their broader intent is to stimulate thought about the long-term impacts of a warmer planet.

GRADE LEVELS

Grades 5–8;9–12

TIME REQUIRED

From one hour for individual exercises to short observation time periods extending over several days to weeks, to intensive time use for constructing scale models.

OBJECTIVES

Through their participation in the six activities that follow, students will:

- Observe how systems change as variables change.
- Observe and describe models to determine the steady state relationships of its variables.
- Explain how changes in the model will change these relationships.
- Use simple scientific tools to measure and record.
- Provide data and conclusions based on the data.
- Apply their knowledge to real life systems.
- Predict how real life systems will be influenced by changes in variables.
- Determine the volume change with time (input rate) with drain closed.
- Make a scale model of a local basin and use it to determine potential effects due to climate change or the seasonal cycle.
- Determine differences in evaporation rates, steady states, open and closed systems, and process.
- Observe and evaluate the Earth's global water balance (global hydrologic cycle).
- Demonstrate that life can promote stability without "thinking" or acting with forethought.

DISCIPLINES ENCOMPASSED

- Earth Systems Science
- Environmental Science
- Geography
- Language Arts
- Mathematics
- Meteorology
- Social Studies

PREREQUISITE KNOWLEDGE: TEACHER

To effectively teach about the effects of climate variability and change, teachers should have a solid understanding of the following concepts.

Teachers should know that:
When approaching Earth System Science (ESS), there are five key elements necessary for a full understanding of the information.

- A Sense of Balance
- An Understanding of Feedbacks
- The Role of Life in Promoting Stability
- A Sense of Change/A Sense of Time
- The Natural-Human Environmental Interaction

PREREQUISITE KNOWLEDGE: STUDENTS

Students must have the following skills and knowledge to complete this activity:

- A primary requirement of any system is that energy and mass must balance. This means that the system must be in equilibrium; its inputs, that which is being put into a system, must equal its outputs, that which is being taken out of the system. When this equilibrium occurs over time it is said to be in a steady state.
- A system can also be characterized according to its stability; its ability to remain the same. They can be stable (unchanging), unstable (existing for a short period of time and then changing) or conditionally stable (staying stable as long as specific conditions are met).
- To determine the volume of water in a tub or aquarium, weigh the aquarium prior to adding the water, and then after the water is added. Then, using the density of fresh water, determine volume using the equation D=M/V. Or, calculate volume using the equation V=L x W x H. Measure the length and width of the tub or aquarium (from the inside). Then take height measurements during the experiment.

KEY TERMS AND CONCEPTS

The following terms and concepts will be presented in the following text and activities:

Albedo
Basin
Conditionally stable
Equilibrium
Feedback
Flux
Greenhouse effect
Greenhouse gases
Input
Negative feedback
Output
Positive feedback
Reservoir
Stable
Steady state
Unstable

SUGGESTED READING/RESOURCES

PUBLICATIONS

Kump, L.R., J.F. Kasting, and R.G. Crane. 1999. ***The Earth System.*** Prentice-Hall, N.J.

Reports to the Nation on Our Changing Planet: Our Changing Climate. Fall 1997. Booklet by NOAA.

WEB SITES

Common Questions About Climate Change
http://www.gcrio.org/ipcc/qa/cover.html

NASA GCMD Learning Center
http://gcmd.nasa.gov/Learning/climate1.html

National Oceanic and Atmospheric Administration (NOAA)
http://www.noaa.gov/

National Climatic Data Center (NCDC)
http://www.ncdc.noaa.gov/ol/ncdc.html

ACTIVITY ONE
A Sense Of Balance

This activity is designed to show how the inputs and outputs of energy or mass in a system balance.

MATERIALS

- A tub with drain and an overflow triangle
- Hose
- Water supply
- Rulers or a scale
- Wax pencil
- Bucket or drain to catch overflow
- Data collection sheet
- Graph paper

PROCEDURE

Step 1
Attach hose to water supply and place the other end into the reservoir (tub). It will be helpful if the volume (or level) of water in the reservoir is easily measurable. Turn the water supply on so that it flows at a steady, controlled rate. It would be a good idea to put the tub at a level lower than the water supply, to prevent splashing (see Figure 1). Determine a set time interval to take measurements.

Step 2
Measure the volume of the water at determined time intervals. Continue to measure volume change as it reaches overflow. Record measurements on your ***Student Activity One Data Collection Sheet: A Sense of Balance.*** Using a wax pencil, mark the water volume (or level) at the point when input and output balance; the system is now in a steady state.

Step 3
Make a graph using the data collection sheet.

Step 4
Answer all questions on the ***Student Activity One Lab Sheet: A Sense of Balance.***

CONCLUSION

Describe what happened in the experiment. Compare this system with ones found in nature. How is it the same? How is it different?

EXTENSION

Try measuring a different variable, such as temperature. Is it in a steady state?

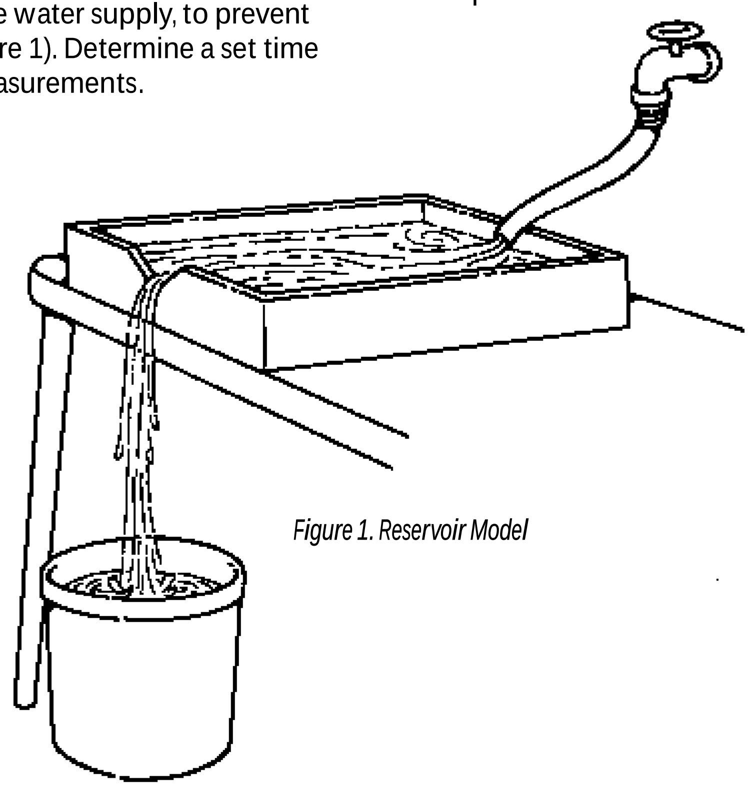


Figure 1. Reservoir Model

Student Activity One Data Collection Sheet: A SENSE OF BALANCE

Name

1. Time interval to take volume measurements:

2. Record measurements:

TIME	**VOLUME**

Student Activity One Lab Sheet: A SENSE OF BALANCE

Name

Use your data to answer the following questions in complete sentences:

1. When is a steady state reached? (In other words, when does input equal output?)

2. What is the area of the overflow triangle?

3. What do you think would happen if the rate of water flowing in was slower? Faster?

4. How would a change in the size and shape of the overflow triangle influence the steady state? In what way does the triangular shape of the overflow triangle act as a feedback?

5. What would happen to the system if the size of the reservoir (tub) was changed?

ACTIVITY TWO
A Sense Of Balance

This activity is designed to use the example in Activity One but will attempt to mirror the inputs and outputs of a local watershed or water reservoir in order to examine how local systems balance in our environment.

MATERIALS

- A tub with drain and an overflow triangle
- Hose
- Water supply with an ability to model the flow rate of a local system
- Bucket or drain to catch overflow
- Input data from local rain gauge stations (get from NOAA or NCDC Home Page) and/or input data from river flow data (river forecast center)
- Maps and/or data about a local reservoir
- Output data such as dam flow or "emergency" release
- Data collection sheet

PROCEDURE

Step 1

Select a water reservoir system that is well known by the students such as a nearby lake, catchment basin, or river reservoir with a dam. Research the typical volume and water level of the selected basin or reservoir.

Step 2

Discuss the possible sources and/or characteristics of water inputs and outputs of the selected basin or reservoir. Collect data on these water inputs and outputs. The key inputs to begin with are water flow (stream or river) into a reservoir and precipitation. The key outputs are any source of water outflow (either based on overflow or dam releases). Other sources or losses of water from the system (e.g., evaporation rate and groundwater flow) may be considered later.

Step 3

Determine the best method to develop a scale model of the selected basin or reservoir, using the hose and water supply to represent the sum of the water inputs, the tub to model the reservoir size, and an overflow drain or triangle to represent the output area (see Figure 2).

At first the scale model should remain simple. Multiple water sources, "drains," and a basin constructed to match the shape and surface area of the real reservoir can be developed in a more realistic attempt to mirror the selected reservoir.

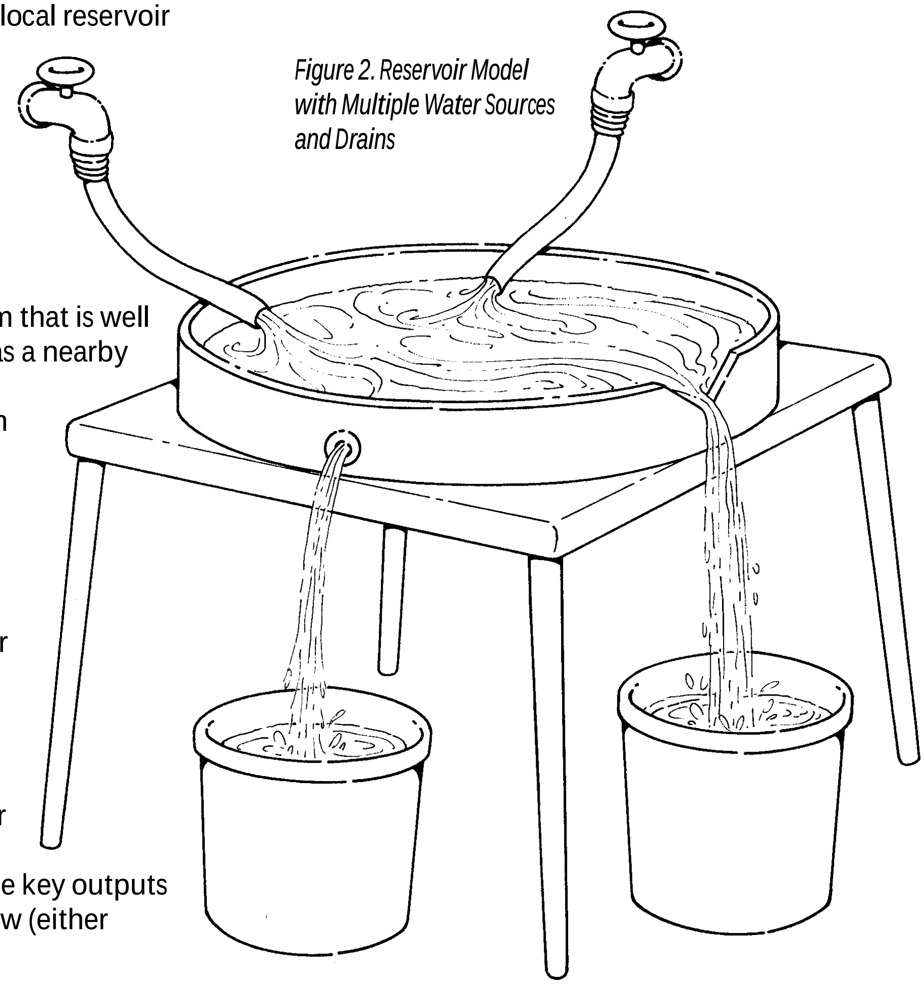


Figure 2. Reservoir Model with Multiple Water Sources and Drains

Step 4

Using data from rain gauges or river flow rates, determine the average water inputs for your model. Then use the scale model to simulate a steady state (or at least average) level for the model reservoir.

Step 5

Using observed data for the region, select water events (e.g., storms with significant precipitation, peak rainfall events, droughts, etc.) or large changes from one season to the next in order to examine the response of your system to a change in water input.

CONCLUSION

- Describe what happened in the experiment.
- How well does the system mirror the historical observations of the basin or reservoir?
- Why might the scale model not replicate the historical observations of water levels in the reservoir?

EXTENSIONS

1. Consider elements of the "balance" which are ignored, such as evaporation and groundwater flow.
2. Consider ways to include other elements into the experimental design, such as local water withdrawal.
3. Develop a reservoir designed to scale and as realistic as possible.

ACTIVITY THREE
A Sense Of Balance

This activity is designed to show how different systems balance due to different environmental conditions.

MATERIALS

- 4 small aquariums
- Soil
- Plants
- 1 cover
- Water
- Graduated cylinder to measure water
- Scale
- Data collection sheets
- Graph paper
- Colored pencils

PROCEDURE

Set up all 4 aquariums at once so that the differences are directly observed.

AQUARIUM 1—
As an Evaporating Pan

Step 1
Place an identical measured amount of water in each aquarium. Use sufficient water to make measurement easy without causing all the aquariums to have water covering the surface. Determine volume and record all values on your ***Student Activity Three Data Collection Sheet:A Sense of Balance—Aquarium 1.***

Step 2
Discuss an appropriate time to take volume readings that match student perceptions on the time that it might take for significant evaporation to take place. Take readings at regular intervals and record this on your data collection sheet. The easiest method of measurement is to weigh the aquarium prior to adding the water and then to weigh the aquarium at the selected intervals, using the density of freshwater to determine the volume (D=M/V). This method can be used to check for the initial volume, which was an identical measured amount of water using the graduated cylinder.

Step 3
Use the observations over an extended period of time to determine the rate of water output (evaporation). The rate of water loss determines the amount of water input needed to maintain a steady state.

AQUARIUM 2—
With Open Top and Soil

Step 4
Place several inches of dry soil in the bottom of the aquarium. Weigh the aquarium with dry soil. Then put in the same amount of water as in Aquarium 1. Check the weight to verify the water volume. Record all values on your ***Student Activity Three Data Collection Sheet: A Sense of Balance—Aquarium 2.***

Step 5
Take readings at the same regular interval as in Aquarium 1 and record measurements on your data collection sheet.

Step 6
Use the observations over an extended period of time to determine the rate of water output (evaporation). The rate of water loss determines the amount of water input needed to maintain a steady state.

AQUARIUM 3—
With Open Top, Soil ,and Plants

Step 7
Place soil and plants in the aquarium. Measure the weight of the aquarium. Then put the same amount of water as in Aquarium 1. Again check the volume by weighing the aquarium including the water. Place all values on your ***Student Activity Three Data Collection Sheet:A Sense of Balance—Aquarium 3.***

Step 8
Take readings at the same regular interval as in Aquarium 1. Record the measurements on your data collection sheet.

Step 9
Use the observations over an extended period of time to determine the rate of water output (evaporation). The rate of water loss determines the amount of water input needed to maintain a steady state.

AQUARIUM 4—Terrarium

Step 10
Place soil and plants in the aquarium with the cover. Measure the weight of the aquarium. Then put the same amount of water as in Aquarium 1. Again check the volume by weighing the aquarium including the water. Place all values on your ***Student Activity Three Data Collection Sheet: A Sense of Balance—Aquarium 4.*** Cover the system (leaving a small gap).

Step 11
Take readings at the same regular interval as in Aquarium 1. Record the measurements on your data collection sheet.

Step 12
Use the observations over an extended period of time to determine the rate of water output (evaporation). The rate of water loss determines the amount of water input needed to maintain a steady state.

Step 13
Make a graph using your data collection sheets, using a different color for each aquarium.

Step 14
Calculate evaporation rates for each aquarium.

CONCLUSION

- How did the characteristics of the aquarium influence the balance of the water? Speculate on the reasons for the differences.
- How did the evaporation rate change with time? Is it the same change for each aquarium? Consider the reasons why the evaporation rate slows as the aquariums dry out and why the aquariums act differently through time.
- How do the results influence your thinking about the real world?

EXTENSION

Consider adding water to the aquariums using your evaporation measurements as a guide in an attempt to maintain a quasi-steady state. Then repeat the experiments to determine how the differences in the aquariums influenced evaporation rates.

Student Activity Three Data Collection Sheet: A SENSE OF BALANCE AQUARIUM 1

Name

1. Volume of water added:

2. Time interval to take volume measurements:

3. Record measurements:

TIME	VOLUME

4. Determine the rate of water output (evaporation) below. Show all work.

5. Amount of water input needed to maintain a steady state:

Student Activity Three Data Collection Sheet: A SENSE OF BALANCE AQUARIUM 2

Name

1. Aquarium weight with dry soil:

2. Volume of water added (same as Aquarium 1):

3. Aquarium weight after water is added:

4. Record measurements (use the same interval as Aquarium 1):

TIME	VOLUME

5. Determine the rate of water output (evaporation) below. Show all work.

6. Amount of water input needed to maintain a steady state:

Student Activity Three Data Collection Sheet: A SENSE OF BALANCE AQUARIUM 3

Name

1. Aquarium weight with dry soil and plants:

2. Volume of water added (same as Aquarium 1):

3. Aquarium weight after water is added:

4. Record measurements (use the same interval as Aquarium 1):

TIME	**VOLUME**

5. Determine the rate of water output (evaporation) below. Show all work.

6. Amount of water input needed to maintain a steady state:

Student Activity Three Data Collection Sheet: A SENSE OF BALANCE AQUARIUM 4

Name

1. Aquarium weight with dry soil, plants, and cover:

2. Volume of water added (same as Aquarium 1):

3. Aquarium weight after water is added:

4. Record measurements (use the same interval as Aquarium 1):

TIME	VOLUME

5. Determine the rate of water output (evaporation) below. Show all work.

6. Amount of water input needed to maintain a steady state:

ACTIVITY FOUR
A Sense Of Balance

This activity is designed to determine global water balance.

MATERIALS

- Pencil and paper
- Calculator (for conclusion activity)

PROCEDURE

Step 1
Divide students into groups of 3 or 4. Have them explain what a global water balance is. Then ask them to make a list of the elements required to complete a global water balance, separating the list into inputs and outputs.

Step 2
Each group will then research and record the methods of measuring the inputs and outputs for different reservoirs (atmosphere, oceans, ice, and land surface).

Step 3
Have the groups create a diagram of the global hydrologic cycle, using the information they obtained from their research. Ask them to consider the limitations of the diagram.

CONCLUSION

- Consider, using references on global warming, how the components of the hydrologic cycle might change with a warming planet.
- Determine the "residence time" of water in the oceans (the sum of the inputs or the outputs divided by the total mass of water in the oceans). What is the significance of this information?

ACTIVITY FIVE

An Understanding Of Feedbacks

AN UNDERSTANDING OF FEEDBACKS

Positive feedbacks amplify a change while negative feedbacks damp a change. Feedbacks are a mode of system "communication." For instance, suppose a small child is crying in a supermarket. As the father gets increasingly frustrated he starts to yell at the child. The child starts to cry even louder so the father gets even more frustrated. He either yells more loudly or perhaps even spanks the child—the result is that the child cries even more loudly. This is a case of a positive feedback. A positive feedback amplifies the change in behavior.

This activity is designed to identify examples of positive and negative feedbacks.

MATERIALS

- Pencil and paper

PROCEDURE

Step 1

As a class, see how many feedbacks students can identify and describe. Work to describe both negative and positive feedbacks. Consider a variety of systems (e.g., the earth, the human body, appliances like an oven, etc.).

Step 2

Describe how the triangular shaped overflow in the first exercise acts as a positive feedback. Consider how the shape of the overflow influences the strength of the feedback.

Step 3

Have students independently research (Kump, Kasting, and Crane has examples) the feedbacks that influence the climate system. Consider the following as examples for research:

- The feedback between a change in global temperature, snow and ice cover, and the reflection of solar energy back to space (albedo).
- The feedback between a change in temperature, evaporation of water, and the greenhouse effect of atmospheric water vapor.
- The feedback between a change in temperature and the rate of radiative energy loss to space.

CONCLUSION

Describe the potential importance of feedbacks (both positive and negative) in governing the response of the Earth system.

EXTENSION

Determine a method of graphing or illustrating positive and negative feedbacks.

ACTIVITY SIX
The Role Of Life In Promoting Stability

THE ROLE OF LIFE IN PROMOTING STABILITY

Homeostasis occurs in a system when a variable is maintained in near equilibrium even though external conditions change. For example, the human body stays at a temperature of 98.6° F (37° C) even though outside temperatures vary greatly. The same is true with an oven. As the oven reaches a set temperature, the thermostat turns the heat off to prevent it from going above the desired temperature. It will then turn the heat back on if it drops below the desired temperature.

This activity is designed to determine the effects life has on temperature stability.

MATERIALS

- Pencil
- Graph paper

PROCEDURE

Step 1
Describe to students a mythical planet called Daisyworld. This planet consists only of dark soil, white daisies, and a sun shining on the planet.

Step 2
Explain that the daisies can't survive in temperatures that are below 5° C (41° F) or above 40° C (104° F). Their optimum temperature is near 25° C (77° F),so at this temperature many daisies cover the planet. Draw a graph to illustrate the relationship between temperature and the number of daisies.
NOTE: °C = (°F-32)/1.8 *or* °F = (°C x 1.8) + 32

Step 3
Since the daisies are white, they tend to reflect solar energy. Since the soil is dark,it tends to absorb solar energy. This suggests that the number of daisies should influence the temperature of Daisyworld. When there are many daisies, more sunlight will be reflectd and the planet should be cool. When there are fewer daisies, the soil should absorb more solar energy and the planet should be warm. Draw a graph that represents this relationship.

Step 4
Combine the 2 graphs on the same graph paper.

Step 5
Use the graphs to define the steady states—these are the points where Daisyworld is in balance (i.e., the number of daisies yields a temperature which is in turn the appropriate temperature for the number of daisies present).

Step 6
Now graphically consider a change to the system.A good test is an arbitrary change in temperature to several degrees warmer (see Figure 3). Start at one of the steady states. Move your pencil to the right (warmer temperature). Then determine the change in the number of daisies that would exist at that temperature by moving your pencil vertically to the line drawn in Step 2. Then consider what the new temperature would be for this number of daisies (using the line drawn in Step 3). Continue this procedure to determine if each steady state point is stable (your pencil returns to the original steady state) or unstable (your pencil moves to a different steady state—extinction of the daisies is one possible solution in the case of an unstable steady state).

CONCLUSION

Life appears to influence the response of Daisyworld to a change in temperature. Yet life does this without thinking about the change. The relationships between temperature and daisies govern a set of feedbacks that in some cases promote stability (a negative feedback) and in other cases promote amplified changes (a positive feedback). Ask students for other examples of systems that behave this way. Describe each.

EXTENSION

Redo the exercise with black daisies and light soil. How do the two exercises differ?

Figure 3. Daisyworld Temperature Graphs

FIGURE 3a

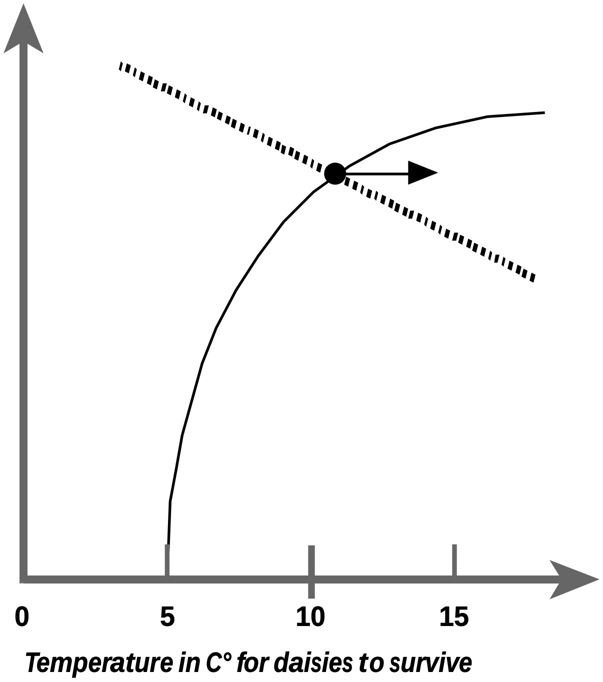


FIGURE 3b

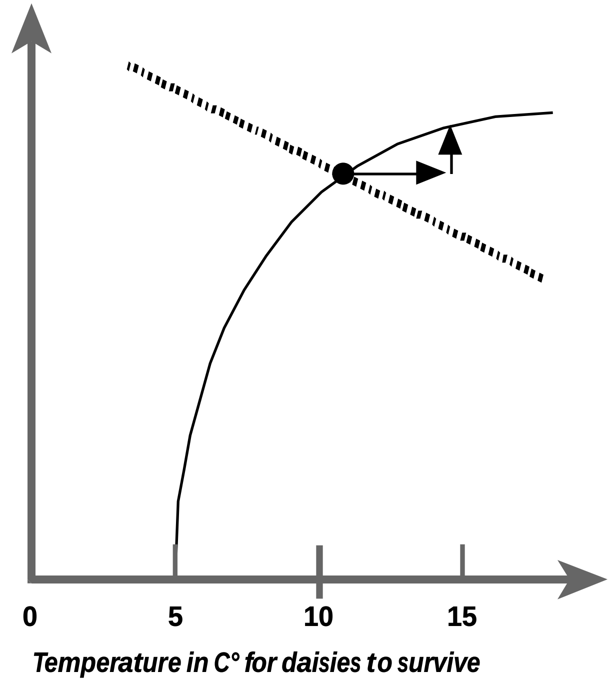


FIGURE 3c

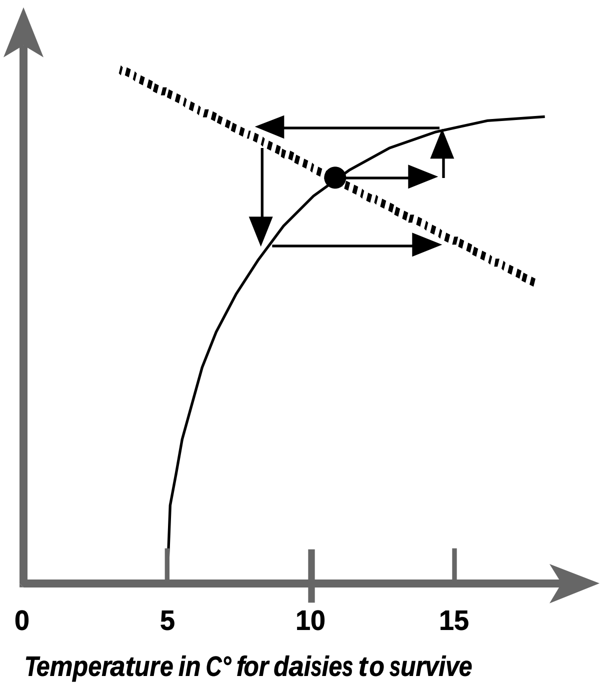
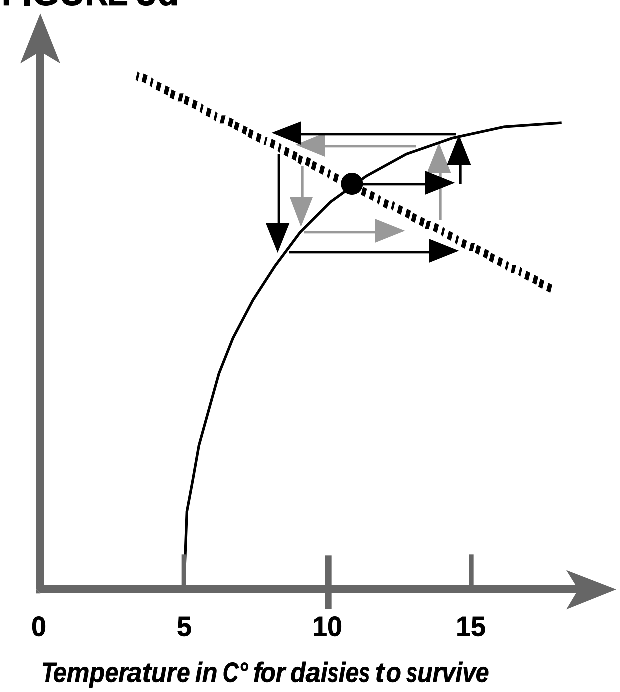


FIGURE 3d



Appendix A
Bibliography

Kump, L.R., J.F. Kasting, and R.G. Crane. 1999. ***The Earth System.*** Prentice-Hall, N.J.

Reports to the Nation on Our Changing Planet: Our Changing Climate. Fall 1997. Booklet by NOAA.

Appendix B
Assessment Rubrics & Answer Keys

Assessment Rubric: ACTIVITY ONE

SKILL	Excellent (4)	Good (3)	Satisfactory (2)	Needs Improvement (1)
Demonstrates ability to properly handle and set equipment up.	Equipment was handled and set up properly.	Equipment was handled properly and set up with few mistakes.	Equipment was mishandled or set up with many mistakes.	Equipment was mishandled and not set up properly.
Accurately takes readings/ measurements.	Readings/ measurements were accurate.	Readings/ measurements had few mistakes.	Readings/ measurements had some mistakes.	Readings/ measurements were inaccurate.
Represents findings clearly on a graph.	Findings are clearly represented.	Findings are represented some-what clearly.	Findings are not represented clearly.	Not able to represent findings.
Able to determine inputs and outputs of a system.	Inputs and outputs were determined.	Many inputs and outputs were determined.	Some inputs and outputs were determined.	Inputs and outputs could not be determined.
Able to make connections between model and systems found in nature.	Able to make many correct connections between model and systems found in nature.	Able to make at least 3 correct con-nections between model and systems found in nature.	Able to make at least 1 correct con-nection between model and systems found in nature.	Not able to make any connection between model and systems found in nature.
Able to determine causes and effects of changes in steady state.	Able to determine causes of observed changes and accurately predict changes in the steady state due to possible changes in the system.	Able to determine causes of observed changes and predict some changes in the steady state.	Able to determine causes of observed changes only.	Not able to determine causes and effects of changes.
Provides logical answers to questions.	All answers are logical.	Provides many answers, most are logical.	Provides few or illogical answers.	Not able to provide answers.

Assessment Rubric: ACTIVITY TWO

SKILL	Excellent (4)	Good (3)	Satisfactory (2)	Needs Improvement (1)
Demonstrates ability to properly handle and set equipment up.	Equipment was handled and set up properly.	Equipment was handled properly and set up with few mistakes.	Equipment was mishandled or set up with many mistakes.	Equipment was mishandled and not set up properly.
Able to determine the inputs and outputs of a natural reservoir system.	Inputs and outputs of a natural reservoir were determined.	Many inputs and outputs were determined.	Some inputs and outputs were determined.	Inputs and outputs could not be determined.
Makes a complete scale model and uses it to determine inaccuracies.	A complete scale model was used and many inaccuracies were determined.	A complete scale model was used and some inaccuracies were determined.	A complete scale model was used but inaccuracies were not determined.	Scale model was not complete and inaccuracies were not determined.
Able to see balance between inputs and outputs, and applies that knowledge to local natural systems.	Able to see balance between inputs and outputs and accurately apply that knowledge.	Able to see balance between inputs and outputs and apply that knowledge with few mistakes.	Able to see balance, but not able to apply knowledge.	Not able to see balance.
Determines responses to changes in the natural reservoir system.	Able to correctly determine responses to changes in the natural reservoir system.	Able to determine some responses to changes in the natural reservoir system with few mistakes.	Able to determine few responses to changes in the natural reservoir system,or responses determined are inaccurate.	Not able to determine responses.
Provide logical answers to questions.	All answers are logical.	Provides many answers, most are logical.	Provides few or illogical answers.	Not able to provide answers.
Determines how different conditions cause different systems of balance.	Correctly determines how different conditions cause different systems of balance.	Determines how some conditions cause different systems of balance.	Determines how some conditions cause different systems of balance, with some inaccuracies.	Not able to determine how different conditions cause different systems of balance.

Assessment Rubric: ACTIVITY THREE

SKILL	Excellent (4)	Good (3)	Satisfactory (2)	Needs Improvement (1)
Demonstrates ability to properly handle and set equipment up.	Equipment was handled and set up properly.	Equipment was handled properly and set up with few mistakes.	Equipment was mishandled or set up with many mistakes.	Equipment was mishandled and not set up properly.
Accurately takes readings/ measurements.	Readings/ measurements were accurate.	Readings/ measurements had few mistakes.	Readings/ measurements had some mistakes.	Readings/ measurements were inaccurate.
Determines the rate of water output for each aquarium.	Correctly determines the rate of water output for all of the aquariums.	Correctly determines the rate of water output for three of the aquariums.	Correctly determines the rate of water output for two of the aquariums.	Correctly determines the rate of water output for only one aquarium.
Determines how the different characteristics of the aquariums caused differences in observed conditions.	Correctly determines how the different characteristics of the aquariums caused differences in observed conditions.	Determines how the different characteristics of the aquariums caused differences in observed conditions with few mistakes.	Determines how the different characteristics of the aquariums caused differences in observed conditions with many mistakes.	Not able to determine how the different characteristics of the aquariums caused differences in observed conditions.
Able to apply knowledge gained from aquariums to the real world.	Able to correctly apply knowledge gained from aquariums to the real world.	Applies knowledge gained from aquariums to the real world with few misunderstandings.	Applies knowledge gained from aquariums to the real world with many misunderstandings.	Not able to apply knowledge gained from aquariums to the real world.
Provides logical answers to questions.	All answers are logical.	Provides many answers, most are logical.	Provides few or illogical answers.	Not able to provide answers.
Represents findings clearly on a graph.	Findings are clearly represented.	Findings are represented somewhat clearly.	Findings are not represented clearly.	Not able to represent findings.

Assessment Rubric: ACTIVITY FOUR

SKILL	Excellent (4)	Good (3)	Satisfactory (2)	Needs Improvement (1)
Determines elements involved to complete a global water balance.	Correctly determines elements involved to complete a global water balance.	Most elements determined are correct.	Some elements determined are correct.	Not able to correctly determine any elements involved.
Researches and collects data.	Collects data that is accurate.	Able to collect data, most of which is accurate.	Able to collect data, some of which is accurate.	Collects inaccurate data.
Creates a diagram of the global hydrologic cycle.	Creates a detailed and accurate diagram.	Creates an accurate diagram that contains most of the important details.	Creates an accurate diagram that is missing important details.	Not able to create an accurate diagram.
Explains the limitations of the global hydrologic cycle diagram.	Accurately explains many limitations of the global hydrologic cycle diagram.	Accurately explains some limitations of the global hydrologic cycle diagram.	Accurately explains some limitations of the global hydrologic cycle diagram, with mistakes.	Not able to determine limitations.
Explains how the components of the hydrologic cycle might change with a warming of the planet.	Gives a detailed explanation of each component and provides accurate predictions.	Gives a somewhat detailed explanation of each component and provides accurate predictions.	Gives a vague explanation of each component and provides predictions.	Not able to explain how the components of the hydrologic cycle might change with a warming of the planet.
Determines the residence time of water in the oceans.	Able to determine the proper equation and make accurate calculations.	Able to determine the proper equation but makes careless calculations.	Uses the wrong equation but makes accurate calculations.	Not able to determine the proper equation or make accurate calculations.
Determines the significance of the residence time of water in the oceans.	Able to determine the significance of the residence time of water in the oceans.	Able to determine the significance of the residence time of water in the oceans with few inaccuracies.	Able to determine the significance of the residence time of water in the oceans with many inaccuracies.	Not able to determine the significance of the residence time of water in the oceans.

Assessment Rubric: ACTIVITY FIVE

SKILL	Excellent (4)	Good (3)	Satisfactory (2)	Needs Improvement (1)
Participates in class discussions.	Frequently participates and behaves appropriately.	Participates sometimes and behaves appropriately.	Participates only with encouragement or behaves inappropriately.	Does not participate and behaves inappropriately.
Able to identify and explain positive and negative feedbacks in natural systems.	Correctly identifies and explains feedbacks.	Identifies and explains feedbacks with few mistakes.	Correctly identifies feedbacks, but unable to correctly explain them.	Not able to correctly identify feedbacks.
Classifies feedbacks of natural systems as positive or negative.	Correctly classifies feedbacks of natural systems as positive or negative.	Classifies feedbacks as positive or negative with few mistakes.	Many errors in classification of feedbacks as positive or negative.	Not able to determine difference between positive and negative feedbacks.
Accurately describes how the overflow in the first exercise acts as a positive feedback.	Accurate description that includes how the shape of the overflow influences the strength of the feedback.	Accurate description not including how the shape of the overflow influences the strength of the feedback.	Description of how the overflow acts as a positive feedback has some mistakes.	Inaccurate description of how the overflow acts as a positive feedback.
Researches and collects data.	Researches and collects data that is applicable.	Able to research and collect data, most of which is applicable.	Able to research and collect data, some of which is applicable.	Researches and collects data that is not applicable.
Research includes elements listed in Step 3.	Research includes all elements listed in Step 3.	Research includes at least two elements from Step 3.	Research includes at least one element from Step 3.	Research does not include elements listed in Step 3.
Describes the potential importance of feedbacks in governing the response of the Earth system.	Describes the potential importance of feedbacks accurately and in detail.	Describes the potential importance of feedbacks accurately with some detail.	Briefly describes the potential importance.	Not able to describe the potential importance.

Assessment Rubric: ACTIVITY SIX

SKILL	Excellent (4)	Good (3)	Satisfactory (2)	Needs Improvement (1)
Sketches a graph illustrating the relationship between temperature in °C for daisies to survive and the number of daisies.	Sketches graph accurately (as a parabola), correct placement of dependent and independent variables, and proper labels.	Able to show two of the preceding.	Able to show one of the preceding.	Not able to sketch a graph, correctly place dependent and independent variables, or label properly.
Determines the relationship between temperature and heat absorption.	The relationship between temperature and heat absorption is correctly described and can be predicted.	The relationship between temperature and heat absorption is described and can be predicted with few mistakes.	The relationship between temperature and heat absorption is correctly described.	The relationship between temperature and heat absorption is not correctly described.
Sketches a graph illustrating the relationship between the temperature in °C due to solar absorption/reflection and the number of daisies.	Sketches graph accurately (as an inverse relationship), correct placement of dependent and independent variables, and proper labels.	Able to show two of the preceding.	Able to show one of the preceding.	Not able to sketch a graph, correctly place dependent and independent variables, or label properly.
Uses the two graphs to determine the steady state for the planet.	Able to combine the two graphs, interpret the information,and make predictions.	Able to do two of the preceding.	Able to do one of the preceding.	Not able to use the two graphs to determine the steady state for the planet.
Analyzes graphs to determine whether each steady state is stable or unstable.	Correctly analyzes all of the steady states.	Correctly analyzes most of the steady states.	Correctly analyzes some of the steady states.	Incorrectly analyzes the steady states.

ANSWER KEY Student Activity One Data Collection Sheet–A SENSE OF BALANCE

Record time interval and measurements to use as a key.

ANSWER KEY Student Activity One Lab Sheet–A SENSE OF BALANCE

1. Answers will vary according to data collected. They should be logical and include supporting data.

2. Answers will vary according to the uniqueness of set-ups. They should be logical and include supporting data.

3. If the rate of water flowing was slower, then it would take longer to reach a steady state and the volume of overflow would decrease. If the rate of water flowing was faster, then it wouldn't take as long to reach a steady state and the volume of overflow would increase.

4. A change in size of the overflow triangle would alter the steady state. A larger size would allow more water to overflow, causing a decrease in the steady state volume. A smaller size would prevent water from overflowing, causing an increase in the steady state volume. A change in shape of the overflow triangle would also alter the steady state. If the shape causes a greater surface area to be in contact with the water, there would be more friction,and less water would be able to overflow. This will cause an increase in the steady state volume. If the shape causes a smaller surface area to be in contact with the water, there would be less friction,and more water would be able to overflow.

If the overflow drain is the shape of a triangle with the point of the triangle facing down,then the overflow drain gets bigger the higher the water gets. This is a feedback in the sense that it slows the rate at which the tub can fill if the size of the overflow increases.

5. There would be a change in the steady state. A larger tub would require a larger volume of water to reach a steady state. A smaller tub would require a smaller volume to reach a steady state.

ANSWER KEY Student Activity Three Data Collection Sheets–A SENSE OF BALANCE

Aquarium 1

1–3. Record volume of water added, time interval,and measurements to use as a key.

4. Use information from Questions 1–3 to make calculations. Make sure labels are included and all work is shown.

Rate of water output (evaporation) = Difference in volume / Difference in time

5. Amount of water input needed to maintain a steady state is the same as the rate of water output (evaporation).

Aquarium 2

1–4. Record aquarium weight with dry soil, volume of water added, time interval,and measurements to use as a key.

5. Use information from Questions 1–4 to make calculations. Make sure labels are included and all work is shown.

Rate of water output (evaporation) = Difference in volume / Difference in time

6. Amount of water input needed to maintain a steady state is the same as the rate of water output (evaporation).

Aquarium 3

1–4. Record aquarium weight with dry soil and plants, volume of water added, time interval,and measurements to use as a key.

5. Use information from Questions 1–4 to make calculations. Make sure labels are included and all work is shown.

Rate of water output (evaporation) = Difference in volume / Difference in time

6. Amount of water input needed to maintain a steady state is the same as the rate of water output (evaporation).

Aquarium 4

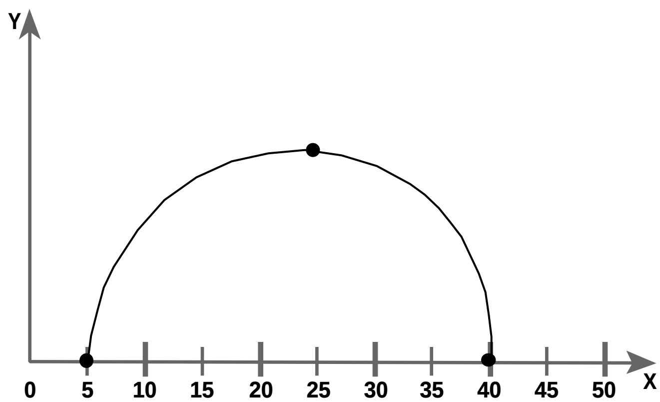
1–4. Record aquarium weight with dry soil and plants, volume of water added, time interval,and measurements to use as a key.

5. Use information from Questions 1–4 to make calculations. Make sure labels are included and all work is shown.

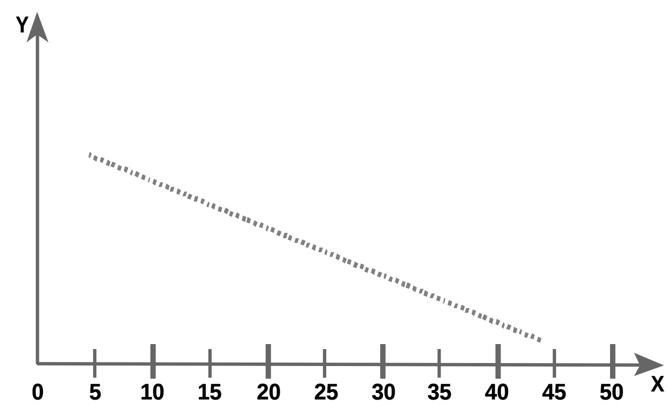
Rate of water output (evaporation) = Difference in volume / Difference in time

6. Amount of water input needed to maintain a steady state is the same as the rate of water output (evaporation).

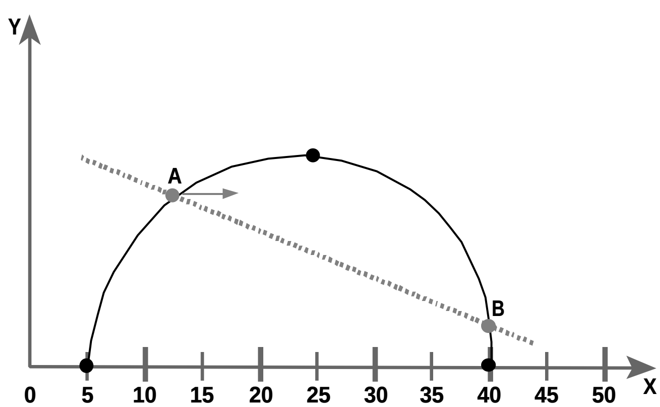
ANSWER KEY Activity Six–THE ROLE OF LIFE IN PROMOTING STABILITY



Temperature in C° for daisies to survive



Temperature in C° due to solar absorption/reflection



Temperature in C° for daisies to survive

Appendix C
National Education Standards

This activity responds to the following National Education Standards:

STANDARDS FOR THE ENGLISH LANGUAGE ARTS

Standard 3: Students apply a wide range of strategies to comprehend, interpret, evaluate, and appreciate texts. They draw on their prior experience, their interactions with other readers and writers, their knowledge of word meaning and of other texts, their word identification strategies, and their understanding of textual features (e.g., sound- letter correspondence, sentence structure, context, graphics).

Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.

Standard 5: Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.

Standard 6: Students apply knowledge of language structure, language conventions (e.g., spelling and punctuation), media techniques, figurative language and genre to create, critique, and discuss different print and non-print texts.

Standard 7: Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and nonprint texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

Standard 12: Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

National Council of Teachers of English and International Reading Association. 1996. ***Standards for the English Language Arts*** *p. 24–46. Urbana, Illinois and Newark, Delaware: National Council of Teachers of English and International Reading Association.*

NATIONAL GEOGRAPHY STANDARDS GEOGRAPHY FOR LIFE

GEOGRAPHY STANDARDS: 5–8

Geography Standard 4: *Places and Regions.* The physical and human characteristic of places.

Geography Standard 7: *Physical Systems.* The physical processes that shape the patterns of the Earth's surface.

Geography Standard 15: *Environment and Society.* How physical systems affect human systems.

Geography Standard 18: *The Uses of Geography.* How to apply geography to interpret the present and plan for the future.

American Geographical Society, Association of American Geographers, National Council for Geographic Education, and National Geographic Society. 1994. ***Geography for Life National Geography Standards*** *p. 143–182. Washington, DC: National Geographic Research and Exploration.*

GEOGRAPHY STANDARDS: 9–12

Geography Standard 7: *Physical Systems.* The physical processes that shape the patterns of the Earth's surface.

Geography Standard 15: *Environment and Society.* How physical systems affect human systems.

Geography Standard 17: *The Uses of Geography.* How to apply geography to interpret the past.

Geography Standard 18: *The Uses of Geography.* How to apply geography to interpret the present and plan for the future.

American Geographical Society, Association of American Geographers, National Council for Geographic Education,and National Geographic Society. 1994. ***Geography for Life National Geography Standards*** *p. 183–222. Washington,DC: National Geographic Research and Exploration.*

CURRICULUM AND EVALUATION STANDARDS FOR SCHOOL MATHEMATICS

CURRICULUM STANDARDS: 5–8

Standard 1: Mathematics as problem solving.

Standard 2: Mathematics as communication.

Standard 3: Mathematics as reasoning.

Standard 4: Mathematical connections.

Standard 5: Number and number relationships.

Standard 7: Computation and estimation.

Standard 8: Patterns and function.

Standard 9: Algebra.

Standard 13: Measurement.

National Council of Teachers of Mathematics. 1989. ***Curriculum and Evaluation Standards for School Mathematics*** *p. 63–119. Reston, VA: The National Council of Teachers of Mathematics, Inc.*

CURRICULUM STANDARDS: 9–12

Standard 1: Mathematics as problem solving.

Standard 2: Mathematics as communication.

Standard 3: Mathematics as reasoning.

Standard 4: Mathematical connections.

Standard 5: Algebra.

National Council of Teachers of Mathematics. 1989. ***Curriculum and Evaluation Standards for School Mathematics*** *p. 121–186. Reston, VA: The National Council of Teachers of Mathematics, Inc.*

NATIONAL SCIENCE EDUCATION STANDARDS

CONTENT STANDARD: K–12

Unifying Concepts and Processes

Standard: As a result of activities in grades K–12,all students should develop understanding and abilities aligned with the following concepts and processes:

- Systems, orders, and organization
- Evidence, models, and explanation
- Consistency, change, and measure

National Research Council.1996. ***National Science Education Standards*** *p. 115–119. Washington,DC: National Academy Press.*

CONTENT STANDARDS: 5–8

Science as Inquiry

Content Standard A: As a result of activities in grades 5–8,all students should develop:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Physical Science

Content Standard B: As a result of activities in grades 5–8,all students should develop an understanding of:

- Transfer of energy

Life Science

Content Standard C: As a result of activities in grades 5–8,all students should develop an understanding of:

- Populations and ecosystems

Earth and Space Science

Content Standard D: As a result of activities in grades 5–8,all students should develop understanding of:

- Structures of the earth system

Science and Technology

Content Standard E: As a result of activities in grades 5–8,all students should develop:

- Abilities of technological design

National Research Council.1996. ***National Science Education Standards*** *p. 143–171. Washington,DC: National Academy Press.*

CONTENT STANDARDS: 9–12

Science as Inquiry

Content Standard A: As a result of activities in grades 9–12,all students should develop:

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Life Science

Content Standard C: As a result of activities in grades 9–12,all students should develop understanding of:

- Behavior of organisms

Earth and Space Science

Content Standard D: As a result of activities in grades 9–12, all students should develop understanding of:

- Energy in the earth system

Science and Technology

Content Standard E: As a result of activities in grades 9–12, all students should develop:

- Abilities of technological design

National Research Council.1996. ***National Science Education Standards*** *p. 173–207. Washington,DC: National Academy Press.*

CURRICULUM STANDARDS FOR SOCIAL STUDIES

Strand 3: *People, Places, & Environments.* Social Studies programs should include experiences that provide for the study of people, places, and environments.

Strand 8: *Science, Technology, & Society.* Social Studies programs should include experiences that provide for the study of relationships among science, technology, and society.

Strand 9: *Global Connections.* Social Studies programs should include experiences that provide for the study of global connections and interdependence.

National Council for the Social Studies. 1994. ***Expectations of Excellence Curriculum Standards for the Social Studies*** *p. 21–30. Washington,DC: National Council for the Social Studies.*

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